CHAPTER 8

BASIC ACTUATING SYSTEMS

Chapter Objective: *Upon completion of this chapter, you will have a working knowledge of the components of the basic actuating systems and their related maintenance procedures.*

The actuating systems consist of the hydraulic components used to direct and control the flow of pressurized fluid as well as the components used to perform the actual work. This chapter begins with a discussion of actuating units, and covers most of the various actuating system components that are used in modern-day hydraulic systems.

ACTUATING UNITS

Learning Objective: *Identify various hydraulic actuating units.*

An actuating unit may be defined as a unit that transforms hydraulic fluid pressure into mechanical force, which performs work (moving some mechanism). Two types of actuating units are used in naval aircraft—actuating cylinders and hydraulic motors. Both types are discussed in this chapter.

TYPES OF ACTUATING CYLINDERS

Actuating cylinders are the most commonly used actuating units in aircraft hydraulic systems. The purpose of an actuating cylinder is to convert fluid under pressure into linear or mechanical motion. Actuating cylinders are generally installed in such a manner that the piston shaft (rod) end of the cylinder is attached to the mechanism to be actuated, with the other end attached to the aircraft structure.

There are two types of actuating cylinders—balanced or unbalanced. Balanced actuators have equal working areas, with a piston shaft extending from both sides of the piston head. This type of cylinder may be a single-acting actuator, which receives hydraulic pressure on only one side of the piston head for movement in one direction, and some other means of force for movement in the opposite direction. However, it may also be a double-acting type, which uses hydraulic pressure alternately on both sides of the piston head to move it in the selected direction.

The most common type of actuating cylinder used on naval aircraft is the unbalanced type, which maybe either single or double acting. Unlike the balanced actuator, it has a single piston shaft extending from the piston head, resulting in unequal working areas. Each actuator used may differ considerably in size and construction.

Single-Acting Actuating Cylinder

The single-acting, piston-type cylinder uses fluid pressure to apply force in only one direction. In some designs of this type, the force of gravity moves the piston in the opposite direction. However, most cylinders of this type apply force in both directions. Fluid pressure provides the force in one direction, and spring tension provides the force in the opposite direction, In some single-acting cylinders, compressed air or nitrogen is used instead of a spring for movement in the direction opposite that achieved with fluid pressure.

Figure 8-1 shows a single-acting, spring-loaded, piston-type actuating cylinder. In this cylinder the spring is located on the rod side of the piston. In some spring-loaded cylinders, the spring is located on the blank side, and the fluid port is located on the rod side of the cylinder.

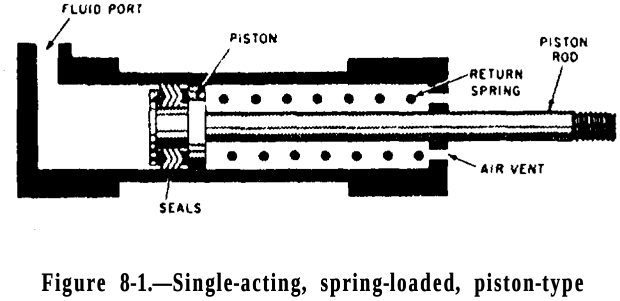


Figure 8-1.—Single-acting, spring-loaded, piston-type actuating cylinder.

A three-way directional control valve is normally used to control the operation of this type of cylinder. To extend the piston rod, fluid under pressure is directed through the port and into the cylinder. See figure 8-1. This pressure acts on the surface area of the blank side of the piston, and forces the piston to the right. This action, of course, extends the rod to the right, through the end of the cylinder. The actuated unit is moved in one direction. During this action, the spring is compressed between the rod side of the piston and the end of the cylinder. Within limits of the cylinder, the length of the stroke depends upon the desired movement of the actuated unit.

To retract the piston rod, the directional control valve is moved to the opposite working position, which releases the pressure in the cylinder. The spring tension forces the piston to the left, retracting the piston rod and moving the actuated unit in the opposite direction. The fluid is free to flow from the cylinder through the port, and back through the control valve to return.

The end of the cylinder opposite the fluid port is vented to the atmosphere. This prevents air from being trapped in this area. Any trapped air would compress during the extension stroke, creating excess pressure on the rod side of the piston. This would cause sluggish movement of the piston, and could eventually cause a complete lock, preventing the fluid pressure from moving the piston. Leakage between the cylinder wall and the piston is prevented by seals. Hydraulic components use seals or gaskets to prevent leakage between static parts (nonmoving), such as a valve body and a hydraulic line fitting. Seals also prevent leakage between dynamic (moving) parts, such as the piston and cylinder wall. The most common seal is an O-ring. Some static seals and all dynamic seals require a backup ring or rings.

Double-Acting Actuating Cylinder

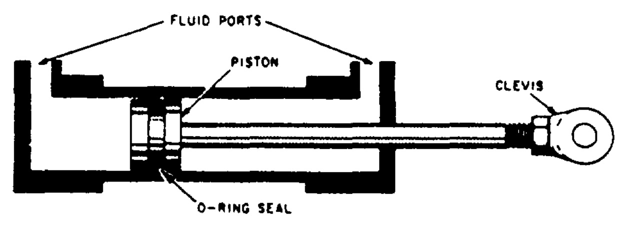
Most piston-type actuating cylinders are double-acting, which means that fluid under pressure can be applied to either side of the piston to provide movement and apply force in the corresponding direction. One design of the double-acting, piston-type actuating cylinder is shown in view A of figure 8-2. This cylinder contains one piston and piston rod assembly. The stroke of the piston and piston rod assembly in either direction is produced by fluid pressure. The two fluid ports, one near each end of the cylinder, alternate as inlet and outlet, depending upon the “direction of flow from the directional control valve.

This is referred to as an unbalanced actuating cylinder; that is, there is a difference in the effective working areas on the two sides of the piston. Refer to view A of figure 8-2. Assume that the cross-sectional area of the piston is 3 square inches and the cross-sectional area of the rod is 1 square inch. In a 2,000 psi system, pressure acting against the blank side of the piston creates a force of 6,000 pounds (2,000 x 3). When the pressure is applied to the rod side of the piston, the 2,000 psi pressure acts on 2 square inches (the cross-sectional area of the piston less the cross-sectional area of the rod) and creates a force of 4,000 pounds (2,000 x 2). For this reason, this type of cylinder is normally installed in such a manner that the blank side of the piston carries the greater load; that is, the cylinder carries the greater load during the piston rod extension stroke.

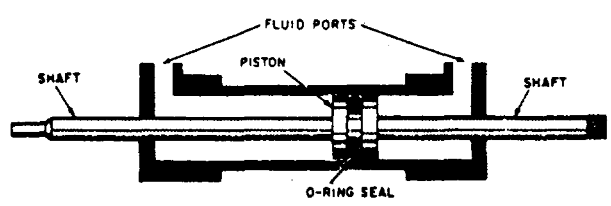
A four-way directional control valve is normally used to control the operation of this type of cylinder. The valve can be positioned to direct fluid under pressure to either end of the cylinder, and to allow the displaced fluid to flow from the opposite end of the cylinder through the control valve to return/exhaust.

The piston of the cylinder shown in view A of figure 8-2 is equipped with an O-ring seal and backup rings to prevent internal leakage of fluid from one side of the piston to the other. Suitable seals and backup rings are also used between the hole in the end cap and the piston rod to prevent external leakage. In addition, some cylinders of this type have a felt wiper ring attached to the inside of the end cap and fitted around the piston rod to guard against the entrance of dirt and other foreign matter into the cylinder.

The actuating cylinder shown in view B of figure 8-2 is a double-acting balanced type. The piston rod



(A) UNBALANCED



(B) BALANCED

Figure 8-2.—Double-acting, piston-type actuating cylinders.

extends through the piston and out through both ends of the cylinder. One or both ends of the piston rod may be attached to a mechanism to be actuated. In either case, the cylinder provides equal areas on each side of the piston so that the amount of fluid and force required to move the piston a certain distance in one direction is exactly the same as the amount required to move it an equal distance in the opposite direction.

Actuators are designed for a particular type of installation. For example, internal locking cylinders are used on some bomb bay door installations, while cushioned types are used where it is necessary to slow the extension or retraction of landing gears.

Mechanical-Lock Actuating Cylinder

In many installations it is necessary to lock an actuating cylinder in a specified position. This may be for safety or operational requirements of the unit. The different designs of lock cylinders vary between manufacturers, but they are usually of the ball-lock or finger-lock type. At times, indicating devices are also incorporated along with the lock feature of the cylinders.

BALL-LOCK ACTUATOR. —The cylinder shown in figure 8-3 is a single-action, ball-lock

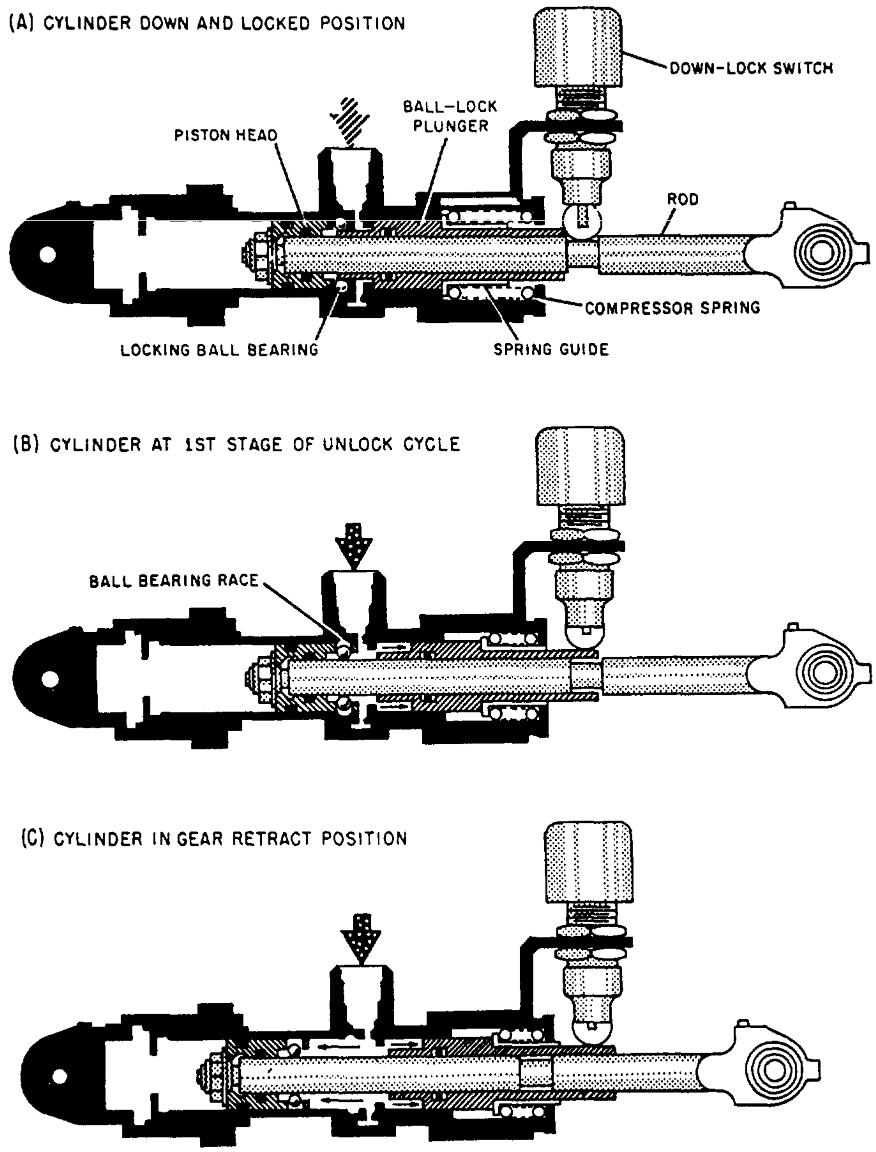


Figure 8-3.—Cutaway of a single-action, ball-lock actuating cylinder.

actuating cylinder. Its purpose is to lock the down-lock mechanism of the landing gear. The ball-lock feature is in the lock position when the landing gear is extended.

The main parts of this cylinder are the body, end caps, piston shaft and head, ball-lock plunger, locking ball bearings, ball bearing race, spring guide, compression spring, and down-lock switch. The operation of the ball-lock actuator is described in the following paragraphs.

When the landing gear is down and locked, the ball-lock actuator will be in the position shown in view A of figure 8-3. Notice the locking ball bearings are being held in the ball bearing race detents by the inner lip of the ball-lock plunger. Since no hydraulic pressure exists while in this position, the spring-loaded, ball-lock plunger is held in its retracted position, allowing the down-lock switch to be actuated by the groove portion of the piston shaft.

When the landing gear selector valve is positioned to its retracted (UP) position, pressurized fluid is allowed to enter the actuator through its only port. This pressurized fluid forces the ball-lock plunger to the right, which simultaneously allows the ball bearings to drop free from their detents in the bearing race and actuate the down-lock switch, as shown in view B of figure 8-3. As soon as the locking ball bearings are released, the piston shaft assembly retracts, as shown in view C of figure 8-3, and unlocks the landing gear. When the landing gear completes its UP cycle, the selector valve returns to neutral, trapping hydraulic fluid within the actuator until the next cycle begins.

FINGER-LOCK ACTUATOR.—The actuating cylinder shown in figure 8-4 is a double-action, two-port, finger-lock, balanced actuator. This type of actuator is currently installed as a main landing gear component on some aircraft. It incorporates an inner cylinder to equalize the displacement of fluid on either side of the piston.

As shown in view A of figure 8-4, an integral, finger-type, spring-loaded, mechanical lock is also incorporated within the actuator to lock the piston shaft assembly in the extended position. The finger-lock actuator has a down-limit switch mounted on and through the cylinder area, which indicates when the landing gear is down and locked; also, an added feature that is common on landing gear actuators is an integral shuttle valve. The shuttle valve allows connection of both the normal extension hydraulic fluid line and the emergency pneumatic extension pressure line. The operation of the finger-lock actuator is described in the following paragraphs.

When the pilot positions the selector valve in the landing gear retracted position, view A of figure 8-4, hydraulic pressure is directed to the cylinder's retract port. Hydraulic pressure entering the cylinder overcomes piston spring force, which permits the locking fingers to open as the piston shaft assembly is retracted into the cylinder.

During normal extension of the landing gear (view B of figure 8-4), hydraulic pressure is directed from the selector valve to the normal extension port of the integral shuttle valve. This pressurized fluid forces the piston towards the extended position. As the piston comes in contact with the locking fingers, hydraulic pressure and spring tension are required to force the piston over the fingers while fully extending the piston shaft assembly. At the same time the piston is being forced over the locking fingers, it contacts the cam-shaped lower end of a toggle shaft, which extends radially into the cylinder area, thereby rotating the shaft. Movement of the toggle shaft is transmitted to the main landing gear down-limit switch, which is attached to the outer surface of the cylinder. This indicates the cylinder is in the locked position.

Control Surface Actuating Cylinder

Actuators are used in conjunction with power-operated flight control systems. Their function is to assist the pilot in handling the aircraft, in the same way as power steering aids in handling an automobile.

In a power-operated flight control system, all the force necessary for deflecting the control surface is supplied by hydraulic pressure. Each movable surface is operated by a hydraulic actuator incorporated in the control linkage. Some aircraft manufacturers refer to these units as power control cylinders; however, all flight control system actuators and power control cylinders perform the same function, and are similar in principle of operation.

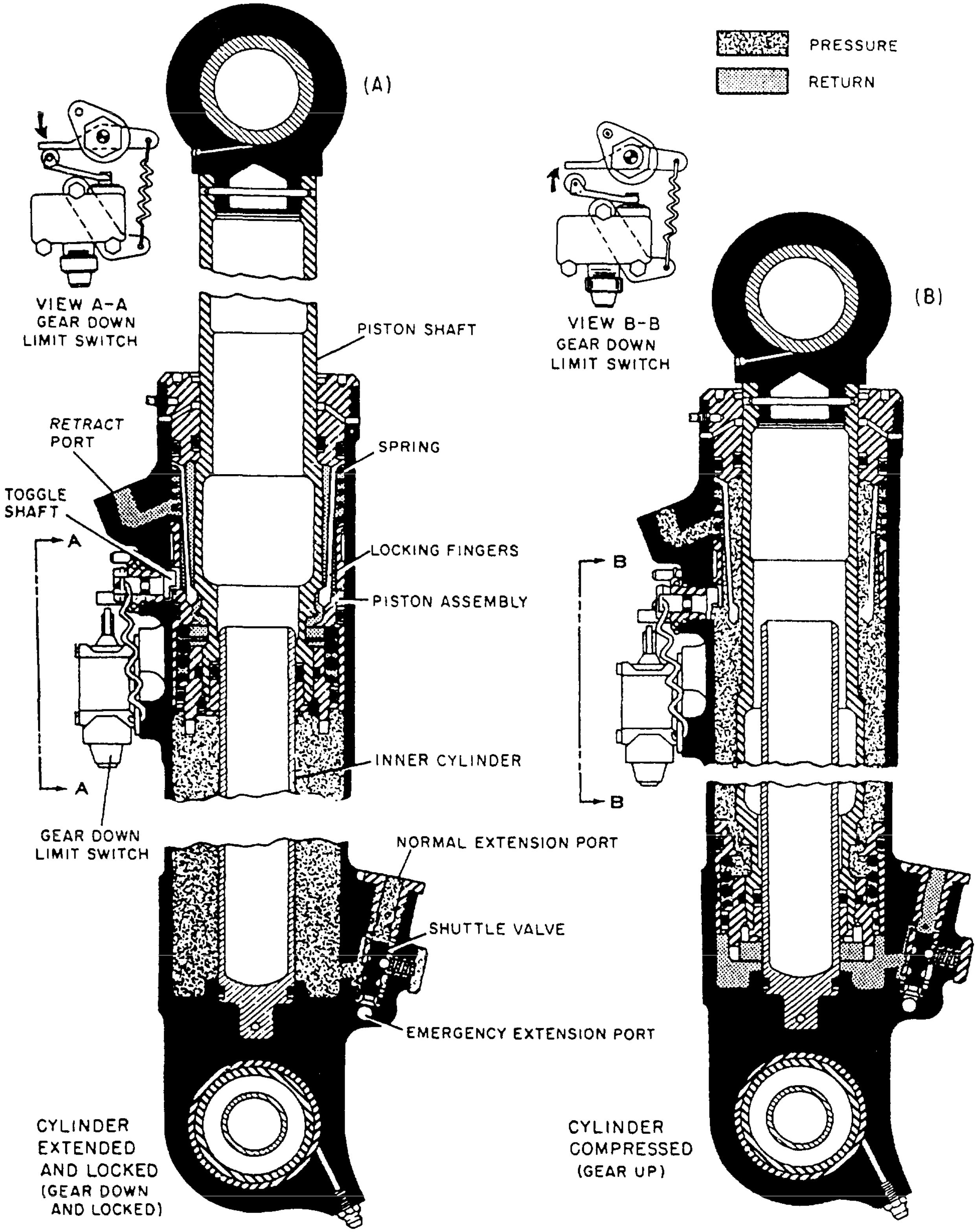


Figure 8-4.—Typical finger-lock actuating cylinder.

A typical flight control surface actuator is shown in figure 8-5. This is a tandem-type hydraulic unit, which means, in this case, that two control valves are incorporated within a common housing. One of the control valves is connected to the aircraft's primary flight control hydraulic system, while the other is connected to a separate hydraulic system.

This is a typical arrangement since Navy specifications require two independent hydraulic systems for operation of the primary flight control systems on all high-performance aircraft.

Although the two control valves in the actuator are interconnected mechanically by a synchronizing rod, they are not interconnected hydraulically. The purpose of the synchronizing rod is to equalize the flow of fluid into the actuator piston chambers.

Because the two control valves operate independently of each other as far as hydraulic pressure is concerned, failure of either hydraulic system does not render the actuator inoperative. Failure of one system does reduce the output force by one-half; however, this force is sufficient to permit handling of the aircraft at certain airspeeds (always well above that required for a safe landing).

This complete actuator consists of the two isolated piston chambers, a shaft assembly with two pistons, two end cap assemblies, the two control valves, and the previously mentioned synchronizing red.

In this particular installation, the piston shaft end is attached to the aircraft structure and remains stationary. The cylinder body is attached to the control surface, and provides control surface deflection by its movement. Two adjustable stops are provided as a means of adjusting actuator movement, thereby limiting the travel of the control surface. When these steps are used in an aileron or elevator control system, one stop limits the UP travel, and the other limits the DOWN travel. In a rudder system, one stop limits the travel to the right, and the other to the left.

MAINTENANCE OF ACTUATING CYLINDERS

During preventive maintenance inspections, you inspect actuating cylinders in accordance with the applicable maintenance requirements cards (MRCs) for the specific aircraft. Actuating cylinders are inspected for leakage and binding. You should clean the exposed portion of the piston shaft with a dry-cleaning solvent, and then wipe it with a clean cloth moistened with hydraulic fluid. All mounting fittings are lubricated with specified grease only.

NOTE: All lubrication fittings and lubrication areas must be cleaned prior to lubrication, and all excess lubricants must be removed at its completion.

External leakage is the most common trouble encountered with actuating cylinders. This can be caused by static or dynamic seals. Static seal leakage around end caps or fittings may be stopped by tightening the affected components or replacing the leaking seal. Dynamic seal leakage around an actuator shaft will require seal replacement. Refer to the appropriate MIM or 03 manual for specific maintenance instructions.

WARNING

Applying too much torque while tightening fittings or other components under pressure may cause catastrophic failure. Such failures can result in injury to personnel or damage to the aircraft.

Internal leakage is harder to detect. This leakage is usually caused by failure of piston seals, and will require repair. Internal leakage is usually indicated by weak, sluggish, or slow movement of the actuator. Refer to the appropriate MIM or 03 manual for repair instructions. This problem is usually resolved by replacement of the actuator. After the repairs are made, you must test the actuator to verify its performance.

HYDRAULIC MOTORS

Hydraulic motors are used to convert hydraulic pressure into rotary mechanical motion. The type of hydraulic motor used in naval aircraft is similar in general design and construction to the piston-type pumps. The difference in the operation of a hydraulic motor and a hydraulic pump is as follows: In the operation of a pump, when the drive shaft is rotated, fluid is drawn into one port and forced out the other under pressure. This procedure is reversed in a hydraulic motor. By directing fluid already under pressure into one of the ports, pressure will force the shaft to rotate. Fluid will then pass out the other port,

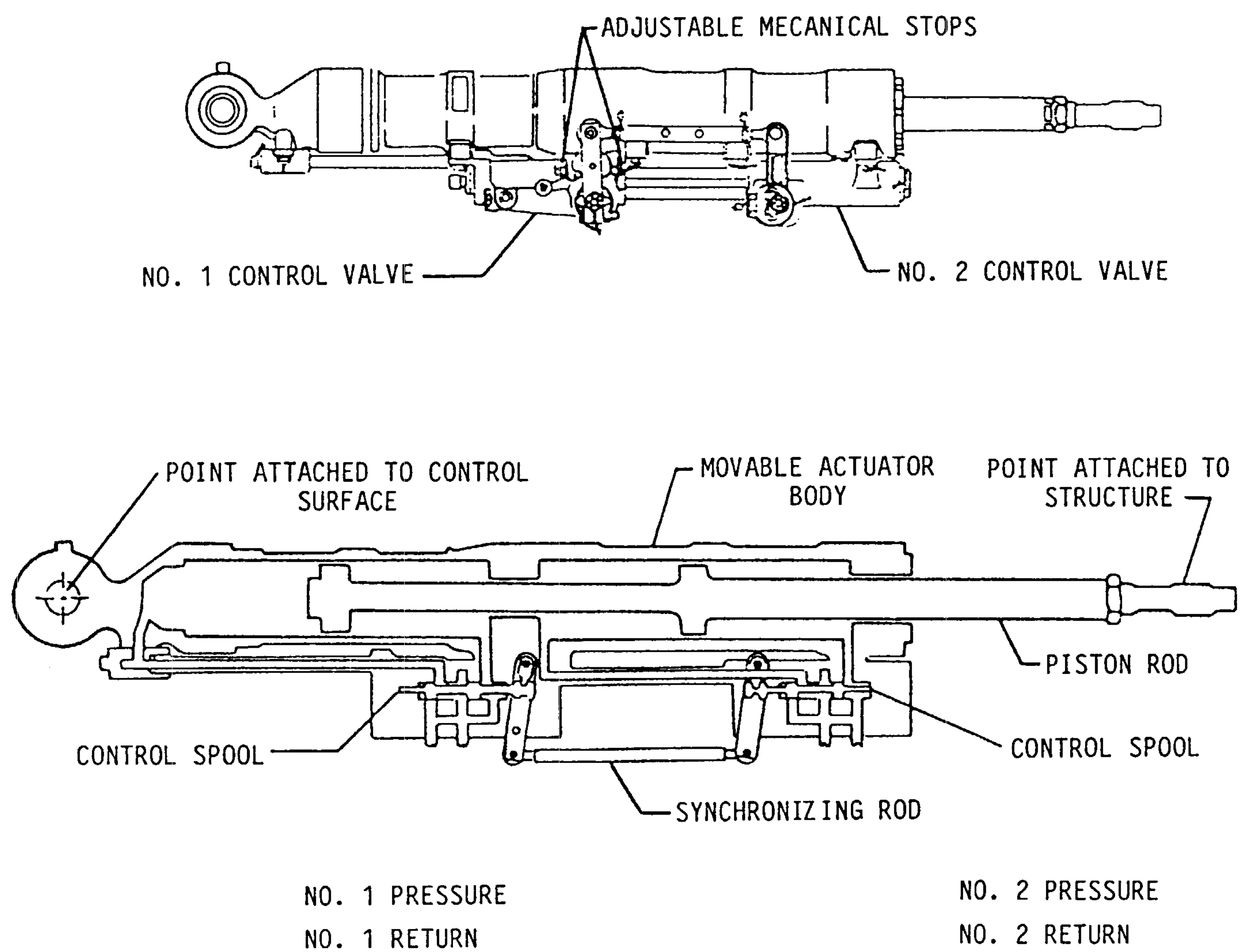


Figure 8-5.–Control surface actuating cylinder.

and back to return. The rotary mechanical force provided by the motor can be used to drive a gearbox, torque tube, or jackscrew.

Hydraulic motors are commonly used cooperate the wing flaps and radar equipment. Hydraulic motors may be operated in either direction of rotation, with the rotation being controlled by the direction of flow to the valve plate ports. The direction of rotation may be instantly reversed without damaging the motor. The direction of flow is controlled by a selector valve.

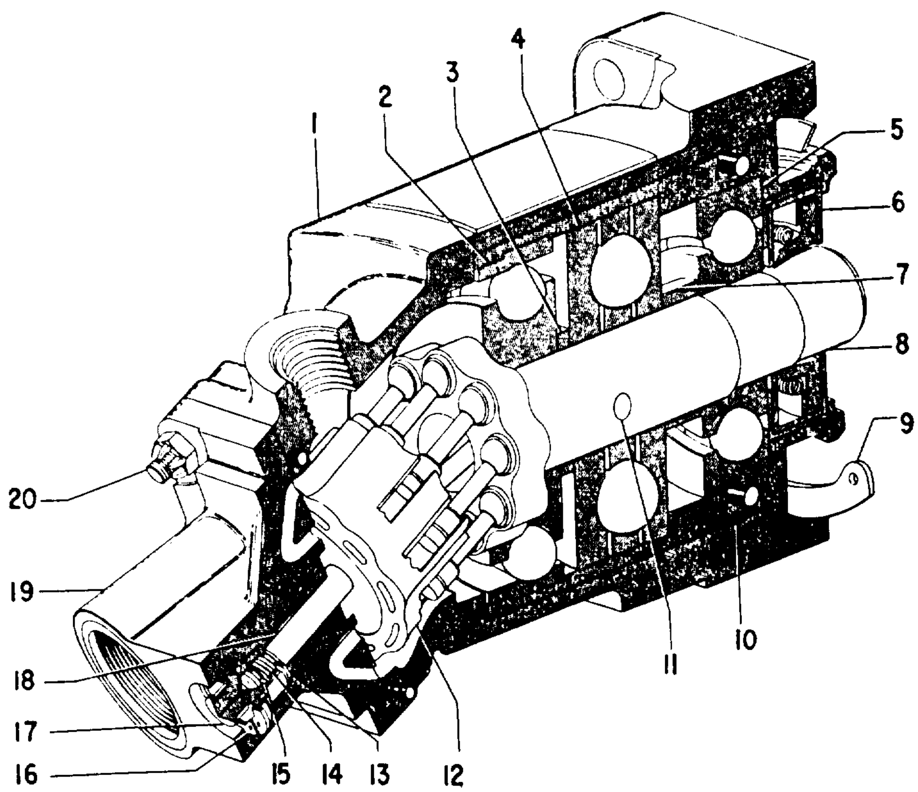
A typical hydraulic motor is shown in figure 8-6. This is a nine-cylinder, fixed-stroke motor. It is self-lubricating and requires no line maintenance other than periodic visual inspection for leakage. The motor is equipped with a stub tooth spline, suitable for engagement into the mechanical linkage of the unit to be actuated on the aircraft.

Any shop maintenance that must be performed on a hydraulic motor should be done in accordance with instructions contained in the applicable Overhaul Instruction Manual (03 series).

VALVES

Learning Objective: *Identify typical valves in a basic actuating system.*

A valve is defined as a device that provides control of the flow or pressure in a hydraulic system.



1. Housing
2. Drive shaft bearing
3. Bearing spacer
4. Thrust bearing
5. Drive shaft bearing
6. Oil seal assembly
7. Bearing spacer
8. Shaft and piston subassembly
9. Retaining ring
10. Bearing and oil seal retainer
11. Universal link retainer pin
12. Cylinder block
13. Spring retaining washer
14. Spring
15. Cap retaining ring
16. Retaining ring
17. Cap
18. Cylinder bearing ring
19. Valve plate
20. Valve plate mounting plate

Figure 8-6.—Typical hydraulic motor.

There are many types of valves, such as selector, pressure reducing, sequence, check, restrictor, and relief. While the basic function for each type of valve is similar, the design and construction may be very different. Examples of these valves are discussed in the following text.

SELECTOR VALVES

Selector valves are used in a hydraulic system to direct the flow of fluid. A selector valve directs fluid under system pressure to the desired working port of an actuating unit (double-acting), and, at the same time, directs return fluid from the opposite working port of the actuating unit to the reservoir.

Some aircraft maintenance instruction manuals (MIMs) refer to selector valves as control valves. It is true that selector valves may be placed in this classification, but you should understand that all control valves are not selector valves. In the strict sense of the term, a selector valve is one that is engaged at the will of the pilot or copilot for the purpose of directing fluid to the desired actuating unit. This is not true of all control valves.

Selector valves may be located in the pilot's compartment and be directly engaged manually through mechanical linkage, or they maybe located in some part of the aircraft and be engaged by remote control. Remote-controlled selector valves are generally solenoid operated.

The typical four-way selector valve has four ports—a pressure port, a return port, and two cylinder (or working) ports. The pressure port is connected to the main pressure line from the power pump, the return port is connected to the reservoir return line, and the two cylinder ports are connected to opposite working ports of the actuating unit.

Three general types of selector valves are discussed in this chapter. They are the poppet, slide, and solenoid-operated valves. Practically all selector valves currently in use come under one of these three general types.

Poppet-Type Selector Valve

Poppet-type selector valves are manufactured in both the balanced and unbalanced design. An unbalanced poppet selector valve offers unequal working areas on the poppets. The larger area of the poppet is in contact with the working lines of the system; consequently, when excessive pressure exists within the working lines due to thermal expansion, the poppet will open. This action allows the excessive pressurized fluid to flow into the pressure line, where it is relieved by the main system relief valve.

The balanced poppet selector valve has equal poppet areas. The poppets will remain in the selected position during thermal expansion of working line fluid. For this reason, thermal relief valves are installed in working lines that incorporate balanced poppet selector valves.

Figure 8-7 shows a typical four-port poppet selector valve. This is a manually operated valve, and consists of a group of conventional spring-loaded poppets. The poppets are enclosed in a common housing and interconnected by passageways to direct the flow of fluid in the desired direction.

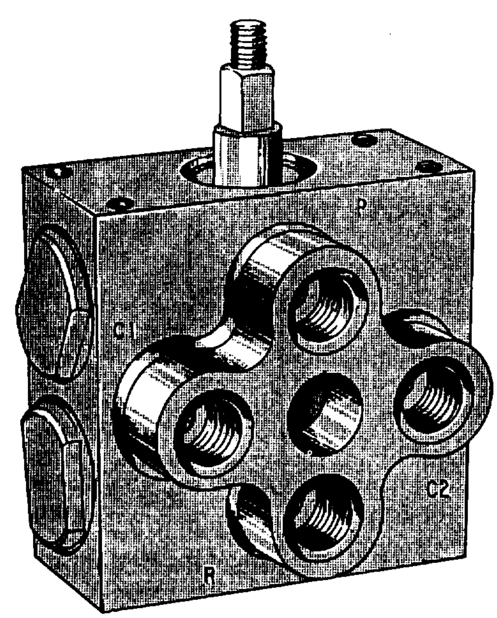


Figure 8-7.—Poppet-type selector valve.

The poppets are actuated by cams on a camshaft, as shown in figure 8-8. They are arranged so that rotation of the shaft by its controlling lever will open the proper combination of poppets to direct the flow of hydraulic fluid to the desired port of the actuating unit. At the same time, fluid will be directed from the opposite port of the actuating unit, through the selector valve, and back to the reservoir.

All poppet-type selector valves are provided with a stop for the camshaft. The stop is an integral part of the shaft, and strikes against a stop pin in the body to prevent overrunning. A poppet selector valve housing usually contains poppets, poppet seats, poppet springs, and a camshaft.

When the camshaft is rotated, either clockwise or counterclockwise from neutral, the cam lobes unseat the desired poppets and allow a fluid flow. One cam lobe operates the two pressure poppets, and the other lobe operates the two return poppets. To stop the rotation of the camshaft at an exact position, a stop pin is secured to the body, and extends through a cutout section of the camshaft flange. This stop pin prevents overtravel by ensuring that the cam lobes stop rotating when the poppets have been unseated as high as they can go, where any further rotation would allow them to return to their seats.

The poppet-type selector valve has three positions-neutral and two working positions. In the neutral position, the camshaft lobes are not contacting any of the poppets. This position assures that the poppet springs will hold all four poppets firmly seated. With all poppets seated, there is no fluid flow through the valve. This action also blocks the two cylinder ports, so when this valve is in neutral, the fluid in the unit system is trapped. To allow for thermal expansion buildup, thermal relief valves must be installed in both working lines.

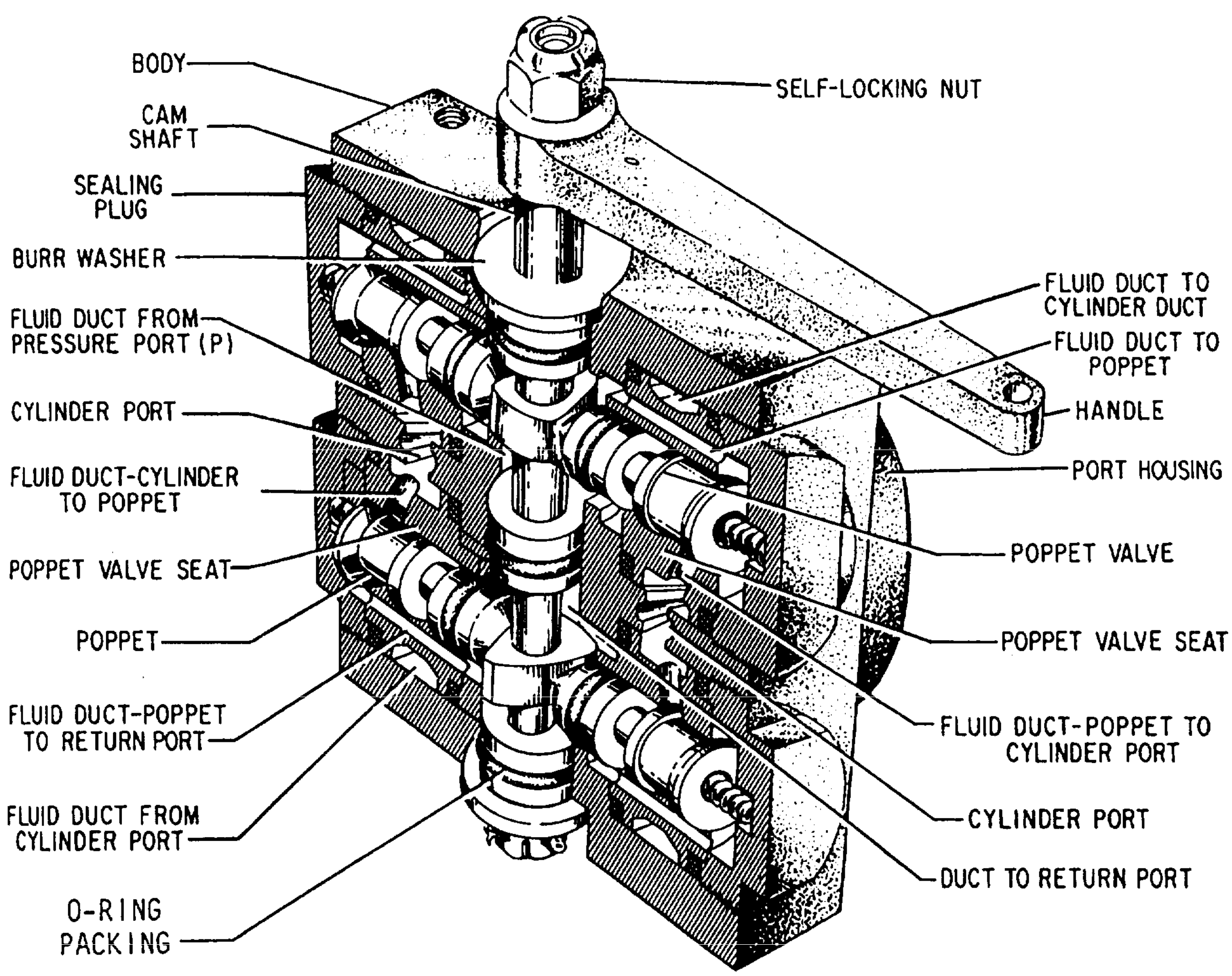


Figure 8-8.—Cutaway view of selector valve body.

You can rotate the camshaft by moving the control handle in either direction from neutral. This action rotates the lobes, which unseat one pressure poppet and one return poppet. See figure 8-9. The valve is now in a working position. Pressure fluid, entering the pressure port, travels through the vertical fluid passages in both pressure poppet seats. Since only one pressure poppet is unseated by the cam lobe, the pressure fluid flows past this open poppet to the inside of the poppet seat. From there it flows out the diagonal fluid passages, and then out one cylinder port and to the actuator.

Return fluid coming from the actuator is coming in the other cylinder port, through the diagonal fluid passages, past the unseated return poppet, through the vertical fluid passages, and out the return port to the system reservoir. By rotating the camshaft in the opposite direction until the stop pin hits, the opposite pressure and return poppets are unseated, and the fluid flow is reversed. This causes the actuator to move in the opposite direction.

Selector valves should be checked periodically for leakage and security of mounting. The operating linkage should be inspected for ease of operation.

Malfunctioning selector valves are usually the result of foreign particles or damaged parts. A malfunctioning valve should be removed and checked for free movement of the camshaft. The valve maybe disassembled and all parts cleaned with clean hydraulic fluid. O-rings should be replaced while the valve is disassembled.

Both external and internal leakage may be caused by damaged or worn O-rings. External leakage could be caused by a damaged gasket under the sealing plug or the end packing on the camshaft. Internal leakage could be caused by a damaged center packing on the camshaft, a damaged bottom gasket on the poppet seat, or a damaged O-ring packing on the poppet.

NOTE: All selector valves that require repair or adjustment must be done in accordance with the applicable MIM or 03 manual. After repair or adjustment, all valves must be tested for proper operation and leakage.

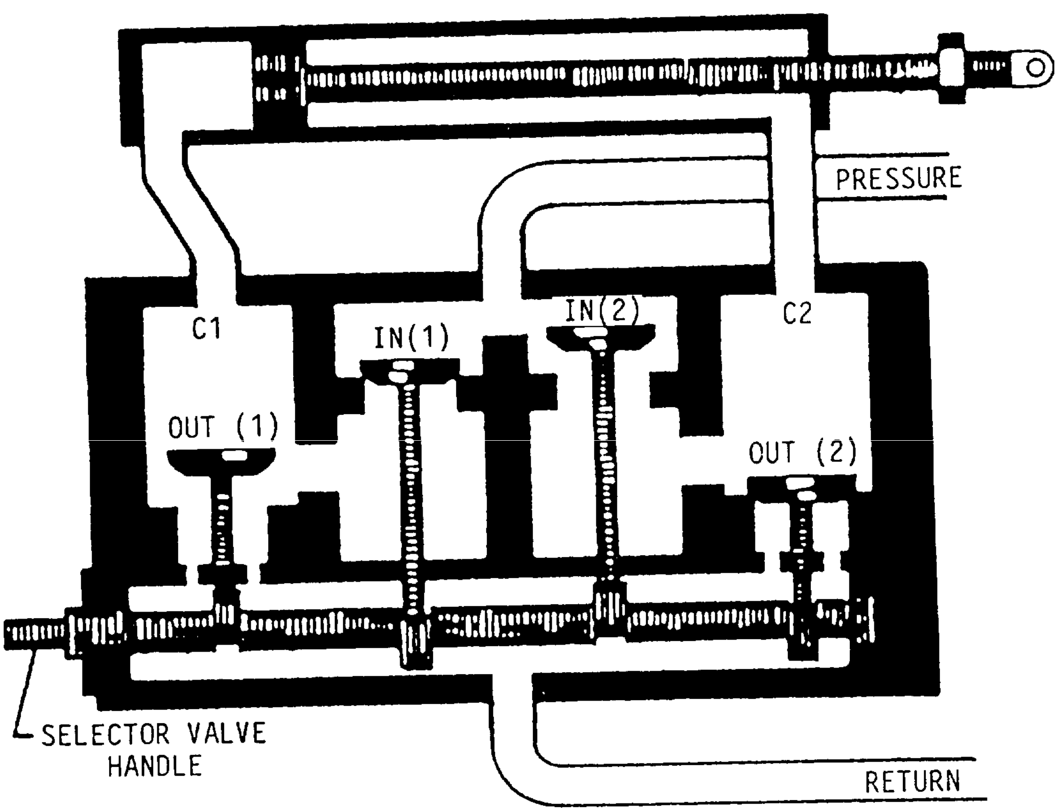


Figure 8-9.—Working view of a poppet-type selector valve.

Slide-Type Selector Valve

The slide-type selector valve is probably the most durable and trouble-free valve currently in use. Some manufacturers refer to this type valve as a piston or spool type. Figure 8-10 shows a cutaway view of a typical four-port slide-type selector valve. The main parts of the valve consist of a body, sleeve, slide, detent springs, and the necessary packings and gaskets.

The valve body is cast aluminum alloy. It has four fluid ports—pressure, return, and two cylinder ports. A large bore has been drilled lengthwise through the body, and all four fluid ports connect into this main bore at intervals along its length. There is also a drilled passageway in the body that runs alongside the main bore. This passageway is used to connect one of the cylinder ports to the return port.

A hollow steel sleeve (3) tits into the main bore of the body. Around the outside diameter of the sleeve are six O-ring gaskets. As the sleeve is inserted into the main bore, these O-rings form a seal between the sleeve and the body. This creates five chambers around the sleeve, and each chamber is formed by two of the O-ring gaskets. Each one of these chambers is lined up with one of the fluid ports in the body. The drilled passageway in the body accounts for the fifth chamber, which results in having the two outboard chambers connected to the return port. The sleeve has a pattern of holes drilled through it to allow fluid to flow from one port to another. A series of holes are drilled into the hollow center of the sleeve between each O-ring gasket.

A steel slide (5) or spool is machined so the largest diameter portions have a close tolerance fit in the sleeve. Typically, the slide has three raised, machined portions known as land areas. These areas usually have several grooves machined into them around the circumference, breaking each area into several lands. The lands (and grooves), in concert with the close machined tolerances, provide for easy, smooth operation, long service, and no leakage.

One end of the slide is connected to the control handle in the cockpit through mechanical linkage. When the control handle is moved, it will then position the slide within the sleeve. The slide lands then line up different combinations of fluid ports, thereby directing a flow of fluid through the valve.

On the end of the slide, next to the eye, are three grooves called “detents.” These detents are used to leek the slide in the exact position needed to properly direct the fluid flow.

The detent spring (6) is a clothespin-type spring, secured to the end of the body by a spring retaining bolt (7). The two legs of the spring extend down through slots in the sleeve and fit into the detents. The slide is gripped between the two legs of the spring. To move the slide, enough force must be applied to spread the two spring legs and allow them to snap back into the next detent, which is another position.

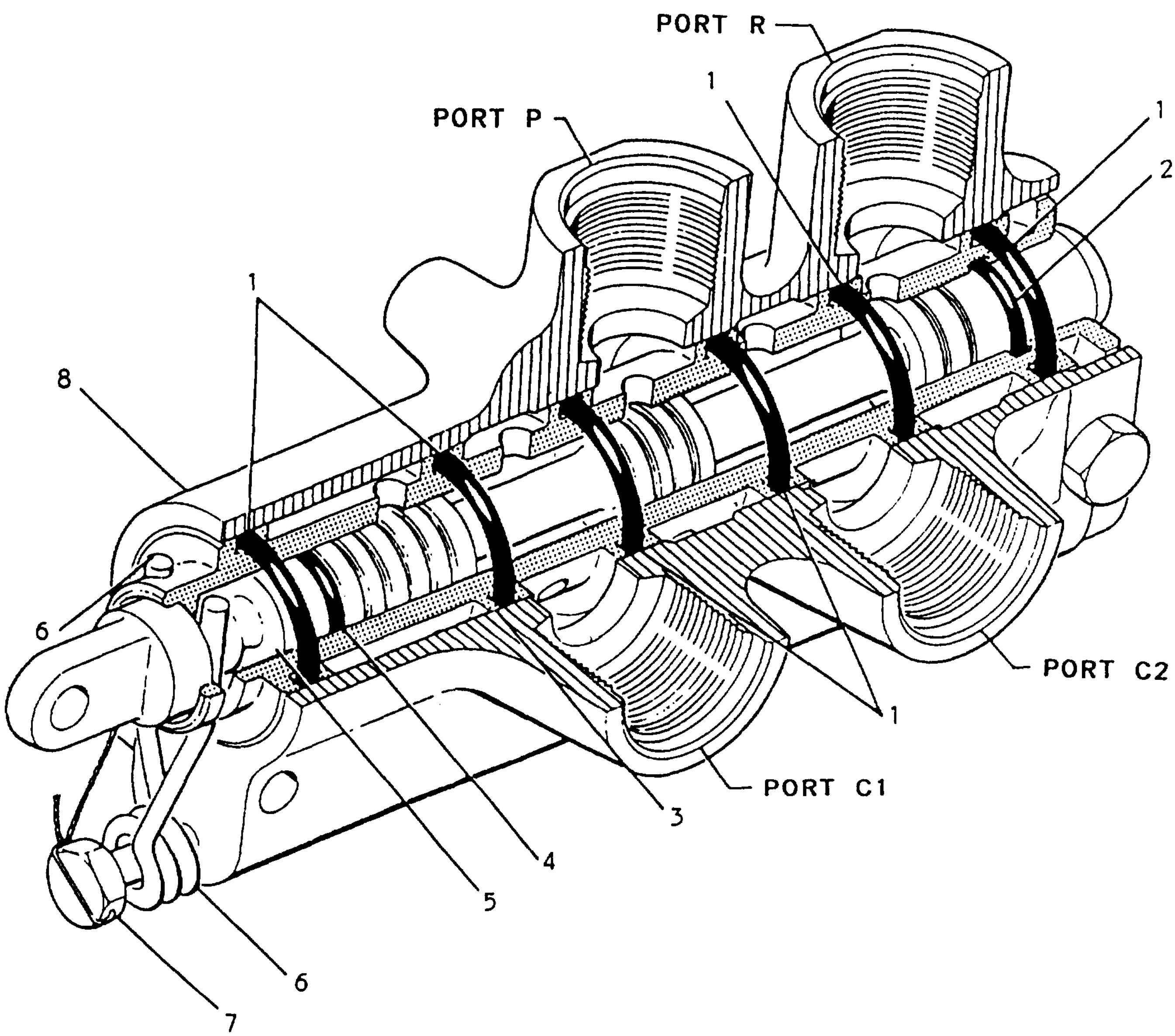
Because of the very close fit between the slide and sleeve, the most common cause of failure or malfunction is the presence of dirt or foreign matter. Foreign matter could result in binding of the slide, scratching the machined surface, and damage to O-rings. Originally, these valves were provided with protective boots on both ends of the slide to prevent dirt or corrosion from getting on the exposed machined surface, where it would be carried into the valve when the slide was moved. These protective boots usually are missing on valves currently issued, leaving the machined surface exposed. As a preventive measure, in place of the boots, a light film of hydraulic fluid should be applied to the exposed areas of the slide. Primarily, this oil film is to prevent corrosion, but it helps to prevent any entry of foreign matter into the valve. Proper linkage adjustment is necessary because linkage that is too long or too short will prevent the detent spring from locking the slide in the correct position.

If it becomes necessary to test this valve under pressure to determine the cause of malfunction, it is important to first check the MIM for the particular installation. A slight amount of internal leakage is permitted in the working positions, and this should not be mistaken for faulty operation.

Solenoid-Operated Selector Valve

A solenoid-operated selector valve is an electrically controlled valve. Solenoid-operated selector valves may be either the slide type or the poppet type. They differ from the manually controlled valves previously described in that they are electrically controlled by one or more solenoids contained within the valve.

A solenoid may be defined as a hollow or tubular-shaped electric coil, made up of many turns of fine insulated wire, that possesses the same properties as an electromagnet. The hollow core imparts linear motion to a movable iron core (or plunger) placed within the hollow core of the solenoid.



1. O-ring gasket
2. O-ring packing
3. Sleeve
4. O-ring packing
5. Slide
6. Detent spring
7. Spring retaining bolt
8. Body

Figure 8-10.—Slide-type selector valve.

Solenoid-operated selector valves are fast becoming the most commonly used vaIves on naval aircraft. Figure 8-11 is a cutaway view of the valve, showing all the principal components. The body is made of cast aluminum alloy and contains four fluid ports. These are the pressure port, return port, and the two cylinder ports.

The body is bored through lengthwise to receive a slide and sleeve assembly similar to the slide-type valve previously described. All four fluid ports lead into this body bore. The ends are closed off by caps or plugs.

A hollow steel sleeve is pressed into the body bore. There are no flanges or grooves machined on the sleeve, but a pattern of holes has been drilled all around it. These holes are arranged in five rings, along the length of the sleeve, drilled through to the hollow center. When the sleeve is installed in the body, each ring of holes will line up with a fluid port. The return port connects to the two outboard rings of holes. To separate each ring of holes around the outside of the sleeve, six O-ring gaskets are installed in the body bore at intervals along its length. The sleeve is then inserted through the centers of the O-rings.

A steel slide is fitted inside the hollow sleeve. The slide has three lands, which form a lapped fit to the inside of the sleeve. Fluid will not flow past them. By properly positioning the slide inside the sleeve, the slide lands will connect different fluid ports by opening or closing the rings of holes in the sleeve. The flow of fluid to and from the actuator is directed by the slide. When the valve is in neutral, the slide is held in the exact center of the sleeve by two coil springs. These springs, working through spring guides, apply equal pressure to each end of the slide. Variation in slide design will determine the valve porting.

To position the slide, apply hydraulic pressure to the working surfaces at each end of it. This pressure is obtained from the pressure port, and is called "bleed pressure." Body passageways direct this pressure to the ends of the slide. Two solenoid assemblies are used to control the flow of bleed pressure.

A solenoid is installed in each side of the valve, pointing toward the center of the body. The solenoids are tubular in shape, with coil wires wound around a hollow center. Hydraulic fluid can enter the center portion, but cannot reach the coil wires. The solenoids are held in place by threaded caps that screw into the body. The function of these solenoids is to control bleed pressure.

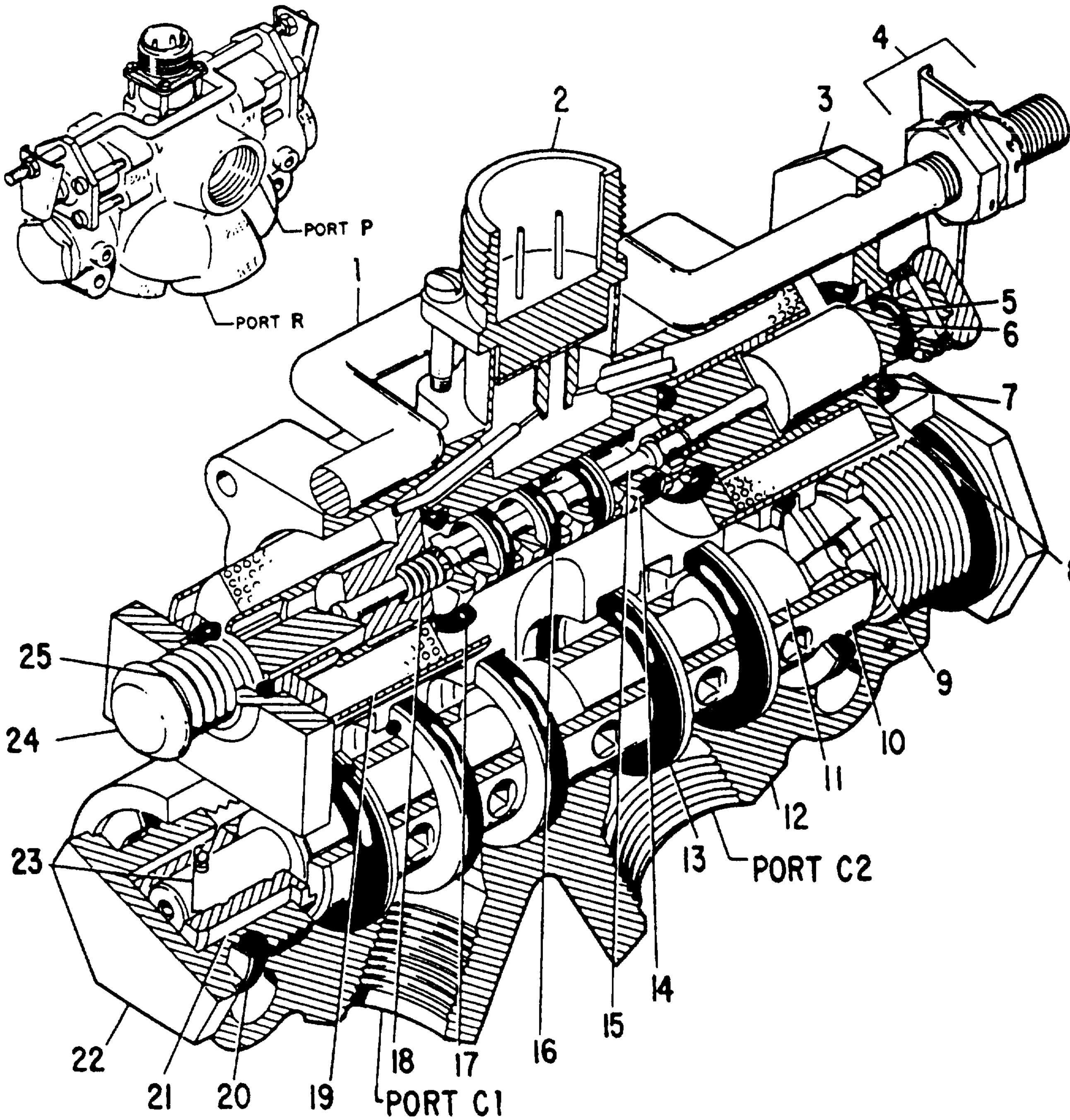
A metal core, called a plunger, is placed in the hollow center of the solenoids. This plunger reacts to the magnetic field created when the solenoid coil is energized. The plunger sits above the level of the coil wires, so that when the solenoid is energized, the plunger is pulled down into the magnetic field. When the plunger is pulled down by the magnetic field, it drives the plunger pin ahead of it. When this happens, the pin opens a passage and relieves bleed pressure from one end of the slide.

During all periodic inspections, selector valves are inspected for security of installation and external leakage. If a malfunction occurs, it must be determined whether the cause is electrical, hydraulic, or material failure. If the aircraft's hydraulic pressure and electrical current are both normal, remove the selector valve and send it to the supporting AIMD. Use the proper 03 series maintenance publication as a guide to clean, inspect, repair, and test the selector valve.

Testing procedures are thoroughly outlined in the MIMs and 03 series manuals. In general, these procedures will consist of checking for internal and external leakage, and on electrically controlled valves, testing the operation of the solenoids. Before applying pressure, make sure all air is bled out of the valve; otherwise, a leak may exist but go undetected. As the testing procedure begins and after the air has been bled, the selector valve shouId be subjected to a low pressure for a short period of time to allow all parts to be lubricated and all O-rings to seat. If the valve is to be stored prior to use, it must be filled with preservative hydraulic fluid, then drip drained before capping.

CHECK VALVES

The purpose of a check valve is to allow the fluid to flow in only one direction. In some installations, such as brake systems, the check valve confines fluid under pressure within the desired section of the hydraulic system. The valve prevents the fluid from reversing its normal direction of flow. The valve prevents pressure from escaping into adjacent sections of the system.



1. Override rod
2. Receptacle
3. Retainer
4. Lever assembly nut
5. O-ring
6. Plunger shaft
7. O-ring
8. Plunger
9. Stop
10. Selector sleeve
11. Selector slide
12. Valve body
13. O-ring and backup ring
14. Pilot sleeve
15. Pilot slide
16. O-ring and backup ring
17. O-ring
18. Pilot spring
19. Solenoid coil
20. O-ring and backup ring
21. Detent stop
22. Plug
23. Position lock assembly (balls and spring)
24. Knob
25. Spring

Figure 8-11.—Solenoid-operated selector valve.

Automatic Check Valves

Automatic check valves contain a seat on which a movable body (ball, cone, or poppet) seats by means of spring tension. See figure 8-12. The valve opens when pressure in the direction of flow (indicated by an arrow on the body of the valve) is strong enough to unseat the movable body. Flow in the reverse direction, along with spring tension, tends to seal the movable body against the valve seat.

When the pressure on the downstream side of the valve exceeds that on the upstream side, the resultant unbalanced force seals the valve closed, as shown in view A of figure 8-12. When the pressure is reversed, the valve is forced open against the tension of the spring, and the fluid flows freely through the valve, as shown in view B of figure 8-12. The tension of the spring is relatively weak, and is intended to be barely sufficient to support the ball in its proper position.

Bypass Check Valves

Bypass check valves serve the same purpose as automatic check valves, but are so constructed that they may be opened manually to allow the flow of fluid in both directions. An example of the possible use of a bypass check valve is in the line between the hand pump and the accumulator. Installation of a bypass check valve in this line would allow hand pump pressure to be directed to either the accumulator or the selector valve.

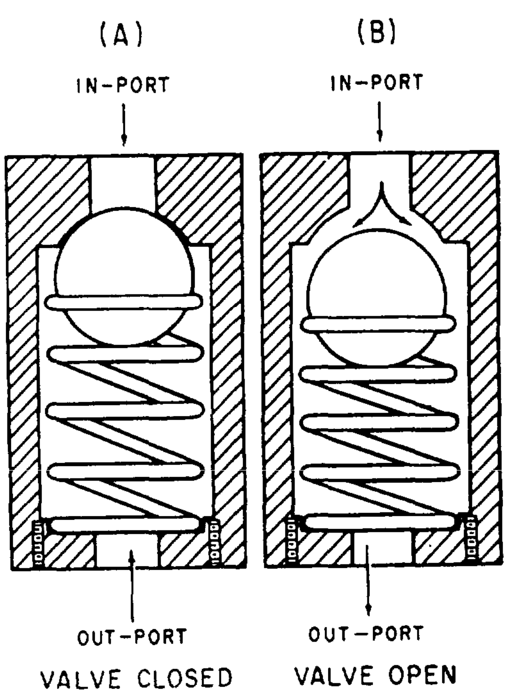


Figure 8-12.—Typical check valve.

Maintenance of Check Valves

Check valves require little attention over long periods of time. Leakage may be caused by the presence of a tiny particle of foreign matter between the checking device (ball, cone, or poppet) and its seat. To remove the foreign matter, it is necessary to remove the valve from the aircraft and completely disassemble the valve. If no scratches are found on the valve seat or the checking device, wash all parts in clean hydraulic fluid of the same type as that used in the system.

While the valve is disassembled, inspect the housing and the checking device for evidence of corrosion. Replace the valve if there is corrosion or excessive roughness. A slightly rough surface can be smoothed by buffing. A cone-type check valve may have a tendency to lean to one side, in which case the movable part may dig into the soft aluminum body of the housing and stick there.

When installing a check valve, remember that the arrow marked on the housing must point in the direction of the flow of the fluid through the valve. Before removing a check valve from a line, it is good practice to mark the adjacent structure, indicating the direction in which the arrow points. Also, observe the following precaution during installation of check valves: Grip the wrench flats of the check valve at the end to which the connecting tubing is being installed. Do not grip the opposite end. This will prevent the possibility of distorting the valve body, causing the valve to leak.

SEQUENCE VALVES

Sequence valves are used to control a sequence of operations; they ensure that actuating units operate at the proper time and in the proper sequence. Sequence valves may be mechanically operated or pressure-operated valves. An example of the use of a sequence valve is in a landing gear actuating system.

In a landing gear actuating system, the landing gear doors must open before the landing gear starts to extend. Conversely, the landing gear must be retracted before the doors close. A sequence valve installed in each landing gear actuating line performs this function.

Sequence valves may be installed in one or both cylinder lines of an actuating system, depending upon the type of action desired. A direct line will go to the first unit to be operated, and a branch line goes from the sequence valve to the second unit.

Mechanically-Operated Sequence Valve

The body of the mechanically-operated (fig. 8-13) sequence valve is usually aluminum, and contains all the working parts. As for the number and location of the fluid ports, there are many variations, depending upon how the valve is to be used. At least two ports are needed. Some models have four ports, and those not needed are plugged. The valve shown in figure 8-13 has two ports.

A contact plunger extends from the body. The plunger is held in the extended position by a plunger spring. The valve is mounted so that the plunger will be depressed by the first unit operated.

A check valve, either a poppet or ball, is installed between the fluid ports of the body, and is held against a seat by the check valve spring. The seated check valve spring prevents fluid flow through the valve. The plunger, driven into the valve by the first unit, unseats the check.

The balanced sequence valve will not permit fluid flow in either direction unless the plunger is depressed. This check valve, with equal working areas (balanced), cannot be unseated by fluid pressure in either direction. Thermal relief valves are needed in this system.

The unbalanced valve can be unseated by fluid pressure below it without having the plunger depressed. This movement allows thermal expansion to be relieved. Thermal relief valves are NOT needed in this system.

Pressure from the selector valve goes directly to the first unit. To operate the second unit, fluid must pass through the sequence valve, which it can do only when the check valve is unseated. On completing its operation, the first unit depresses the plunger on the sequence valve, which unseats the check valve and allows fluid to flow through the valve to second unit. Thus, the second unit cannot operate until the first unit operation is complete. In reverse, when contact force is removed from the plunger, the spring extends it and the check valve reseats.

Improper adjustment of plungers on the mechanical-type sequence valve is the most common cause of trouble. If the adjustment is off, it could cause the second unit to operate too soon or not at all. The adjustment is made either on the plunger of the sequence valve or the striker that depresses the plunger.

Adjustment should be checked at every periodic inspection. If a valve leaks internally, disassemble, clean, and inspect the check valve and its sealing surface. Replace faulty O-rings. Internal leakage could cause the second unit to operate before it should.

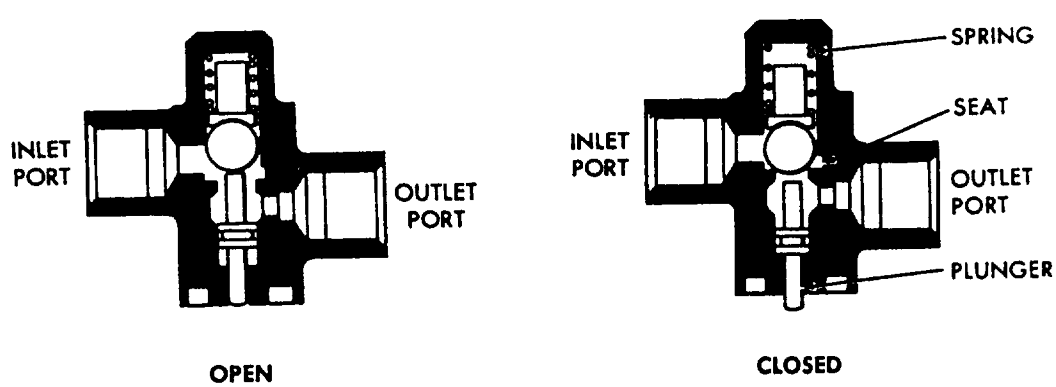


Figure 8-13.-Typical sequence valve.

Pressure-Operated (Priority) Sequence Valve

The pressure-operated sequence valve, also called a priority valve, looks like a check valve externally. Like a check valve, the installation position is indicated by an arrow. Figure 8-14 shows this valve installed in a wing fold system.

During the wing folding cycle, pressure-operated (priority) valves sequence the movement of the lockpins and fold actuators. These valves ensure lockpin actuation before fold actuator operation. This completely automatic valve consists of a body containing a spool, seat, poppet, related springs, seals, and an end cap.

When the wing fold selector valve is in the fold position, it directs fluid both to the wing lockpin and to the pressure-operated sequence (priority) valve. System pressure drops in the wing fold system because of the amount of pressurized fluid needed to actuate the lockpins. This lowers pressure below that needed to open the pressure-operated (priority) valve.

View A of figure 8-14 shows insufficient pressure to unseat the spool. When lockpins have completed their travel, system pressure builds until it overcomes spring tension and causes the poppet to unseat the spool (view B of fig. 8-14). Fluid then flows freely through the valve to the wing fold actuators.

View C of figure 8-14 shows the free-flow position of the valve. When spreading the wings, return fluid moves the seat from the spool compressing the poppet spring, which causes the poppet to bottom and allows free flow of fluid through the valve.

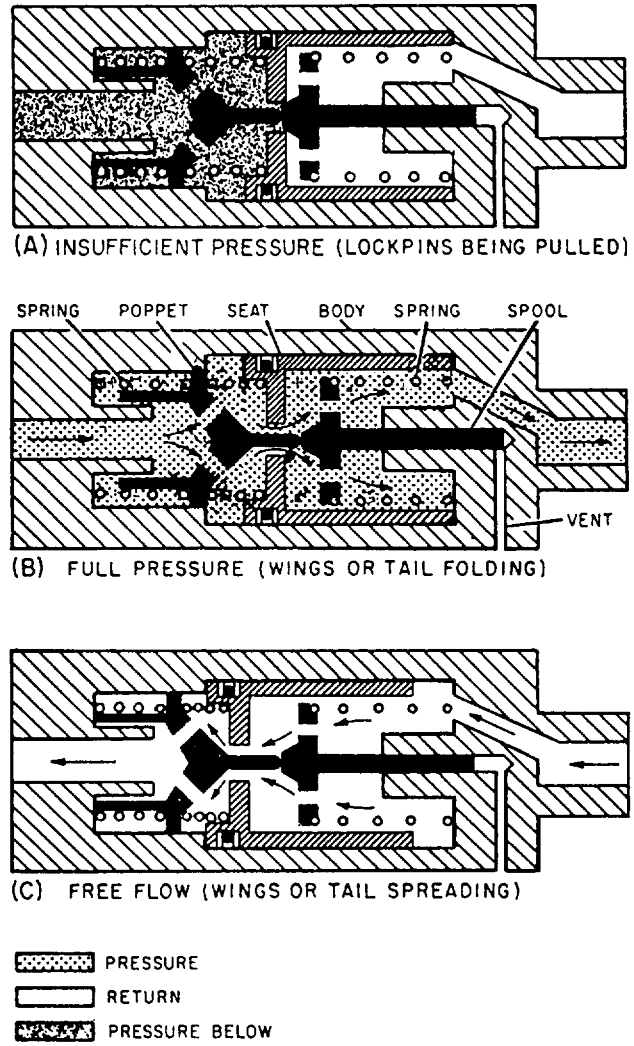


Figure 8-14.—View of priority valve.

SHUTTLE VALVES

All aircraft incorporate emergency systems that provide alternate methods of operating essential systems required to land the aircraft safely. These emergency systems usually provide pneumatic or hydraulic operation of the essential systems; however, in some cases due to the design, they maybe operated satisfactorily through mechanical linkage. When using the pneumatic or hydraulic emergency system, that pressure must be directed to the unit concerned; emergency pressure must not enter the normal system, especially if the pneumatic type system is used. To allow operating pressure to reach the actuating unit and still not enter the other system, a shuttle valve is installed in the working line to the actuating unit. The main purpose of the shuttle valve is to isolate the normal system from the emergency system.

Shuttle valves are located close to the actuating unit concerned. This location reduces to a minimum the units to be bled and isolates as much of the normal system from the emergency system as possible. In some installations, the shuttle valve is an integral part of the actuating unit.

A typical shuttle valve is shown in figure 8-15. The body contains three ports-the normal system inlet port, the emergency system inlet port, and the unit outlet port. A shuttle valve used to operate more than one actuating cylinder may contain additional unit outlet ports.

Enclosed in the body is a sliding part called the shuttle. It is used to seal one of the two inlet ports. A shuttle seat is installed at each inlet port. During operation, the shuttle is held against one of these seats, sealing off that port. These parts are held in the body by end caps. External leakage is prevented by an O-ring gasket at each end cap.

Operation of Shuttle Valves

When a shuttle valve is in the normal operating position, fluid has a free flow from the normal system inlet port to the unit outlet port. The shuttle is seated against the emergency inlet port, and held there by the shuttle spring or by normal system pressure. The shuttle remains in this position until the emergency fluid, gas, or air is released under pressure by the emergency control valve. The application of emergency pressure at the emergency inlet port forces the shuttle from the emergency inlet port seat to the normal system inlet port seat. The emergency pressure then has a free flow to the unit outlet port, but is prevented from entering the normal system by the shuttle.

Maintenance of Shuttle Valves

Shuttle valve maintenance is generally limited to repairing leakage. External leakage may generally be repaired by tightening the end caps. If this does not stop excessive leakage, the end cap O-rings should be replaced.

Internal leakage can usually be repaired by removing and flushing the unit with clean hydraulic fluid. Excessive heating is a good indication of internal leakage through a shuttle valve. Excessive cycling of the emergency system pump is also an indication of a leaky shuttle valve.

After an emergency system has been operated, all emergency system pressure should be bled off as soon as possible, and the normal system restored to operation.

RESTRICTORS

Restrictors are used in hydraulic systems to limit the flow of hydraulic fluid to or from actuators where speed control of the cylinders is necessary to provide specific actions. If control in one direction only is desired, a one-way restrictor is used. If restricted fluid flow both to and from an actuating cylinder is necessary, a two-way restrictor is installed.

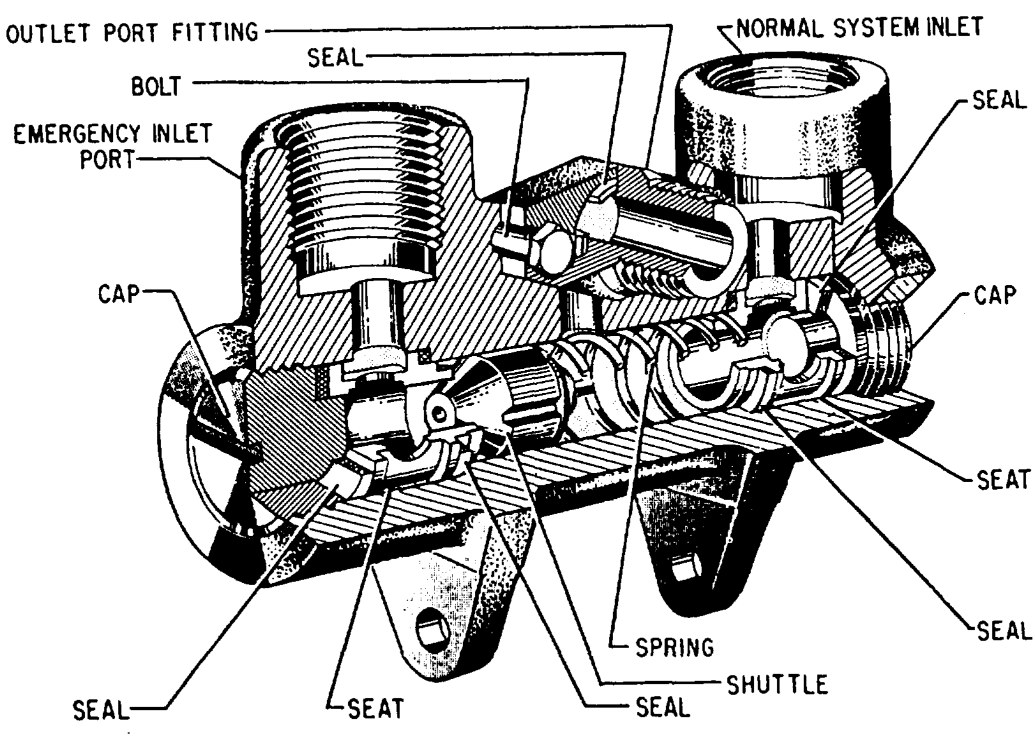


Figure 8-15.—Shuttle valve.

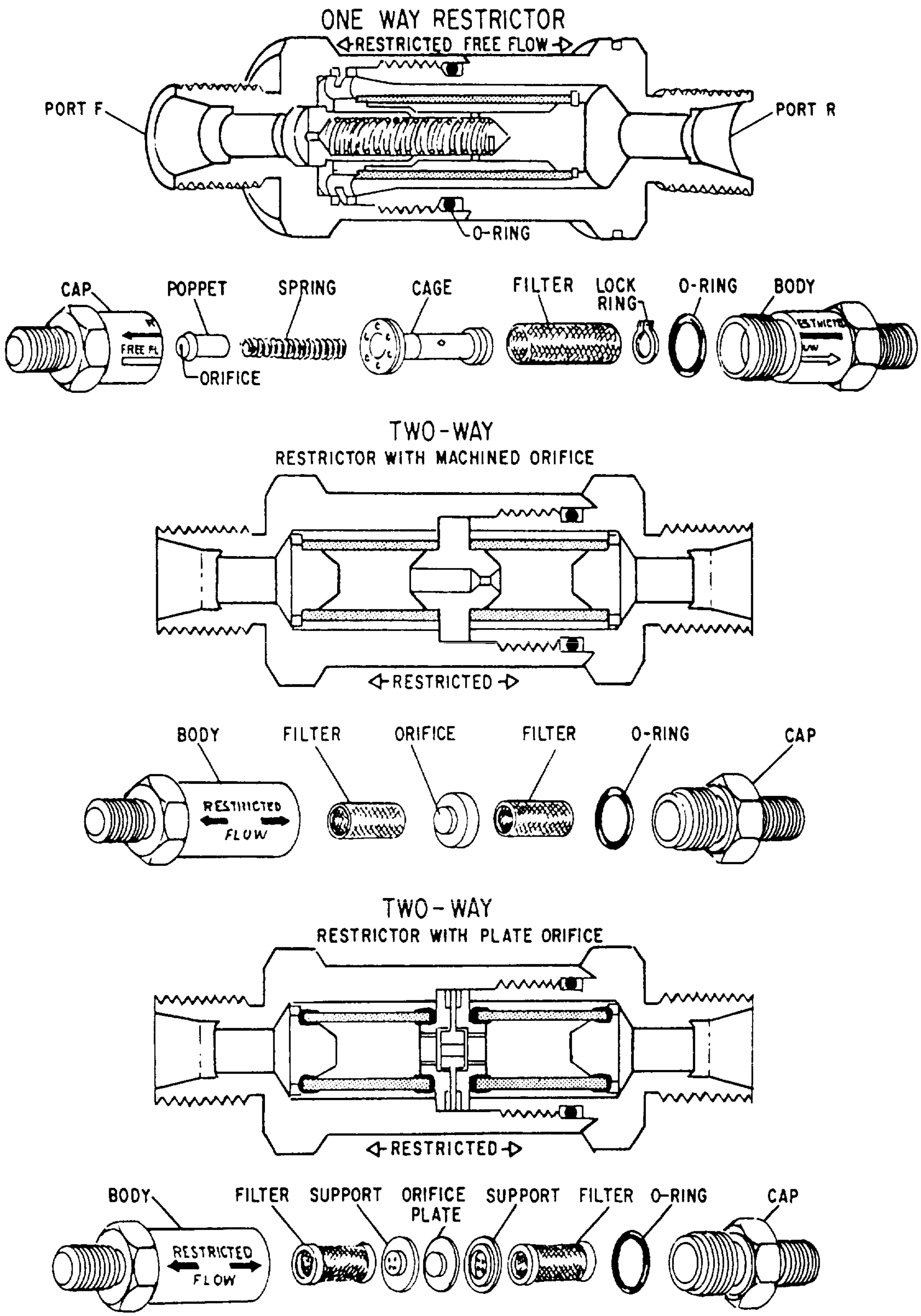


Figure 8-16.—Restrictors.

One-Way Restrictor

One-way restrictors provide reduced hydraulic flow in one direction only, to limit actuating speed of hydraulic cylinders for the purpose of proper timing or sequence of operation. Also, they provide free flow of fluid in the opposite direction to permit the actuating cylinder to actuate at a faster rate of speed during the reverse action of the cylinder.

One-way restrictors are used in some landing gear systems to regulate the speed and sequence of landing gear retraction or extension. If sequenced action (that is, one cylinder to be actuated before other cylinders on the same line) is desired, one-way restrictors are placed in the line upstream of all cylinders except one.

Figure 8-16 shows both the one-way and two-way restrictors. The main parts of a one- way restrictor are the cylindrical body and cap, which contain a spring-loaded poppet, a cage, and a stainless steel filter element.

The one-way restrictor allows free flow in one direction and restricted flow in the opposite direction. Both directions of flow are indicated by arrows found on the body of the valve.

In a restricted direction, pressurized fluid entering port R (fig. 8-16) flows through the filter assembly and enters the cage through drilled passages. Fluid from the interior of the cage is forced through the poppet's orifice, thus causing the required metering action.

In the free flow direction, pressurized fluid entering port F overcomes poppet spring tension and allows fluid to flow past the poppet's seat, through drilled passages within the larger flange of the cage, and out through port R.

Two-Way Restrictor

Two-way restrictors are used to limit the flow of hydraulic fluid where it is desirable to retard the action of a hydraulic cylinder in both directions. Figure 8-16 shows two types of two-way restrictors, one of which has a machined orifice with two integral stainless steel filters. The other type shown contains an orifice plate between two stainless steel filters. The filters contained within the restrictors are identical in construction and provide protection in both directions of flow. The filter size specification for the two-way restrictor is identical to those found within one-way restrictors.

Two-way restrictors, regardless of whether they are of the machined orifice type or of the plate orifice type, operate identically. Fluid entering either port is filtered prior to flowing through the orifice, thus protecting the orifice from possible stoppage. As the fluid is metered through the orifice, the prescribed rate flow is directed out the opposite port of the restrictor and to the actuating unit.

Maintenance of Restrictors

Maintenance of restrictors is usually limited to checking for external leakage and the required fluid flow. The specific MIM lists the required fluid flow in gallons per minute (gpm) for each size of orifice being checked. It also specifies the correct pressures to use as well as the required procedures during each check.

PRESSURE-REDUCING VALVES

Pressure-reducing valves are used in hydraulic systems where it is necessary to lower the normal system operating pressure a specified amount.

Figure 8-17 shows the operation of a pressure-reducing valve. View A of figure 8-17 shows system pressure being ported to a subsystem

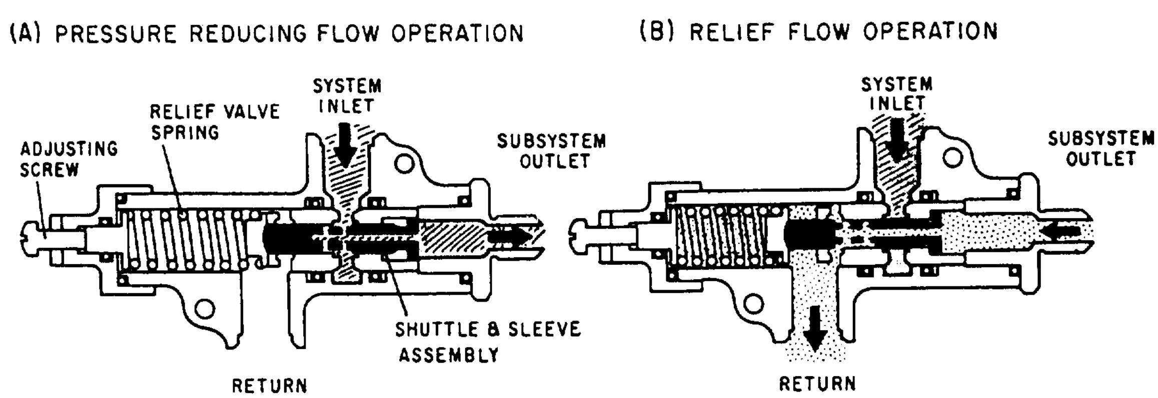


Figure 8-17.—Pressure-reducing valve operational schematic.

through the shuttle and sleeve assembly. Subsystem pressurized fluid works on the large flange area of the shuttle, which causes the shuttle to move to the left after reaching a specified pressure, thus closing off the normal system. The valve will stay in this position until the subsystem pressure is lowered, at which time the shuttle will move to its prior position and allow the required amount of pressurized fluid to enter the subsystem. During normal operation of the subsystem, the pressure-reducing valve continuously meters fluid to the subsystem.

HYDRAULIC FUSES

A hydraulic fuse is a safety device. Fuses may be installed at strategic locations throughout a hydraulic system. They are designed to detect line or gauge rupture, fitting failure, or other leak-producing failure or damage.

One type of fuse, referred to as the automatic resetting type, is designed to allow a certain volume of fluid per minute to pass through it. If the volume passing through the fuse becomes excessive, the fuse will close and shut off the flow. When the pressure is removed from the pressure supply side of the fuse, it will automatically reset itself to the open position.

Fuses are usually cylindrical in shape, with an inlet and outlet port at opposite ends, as shown in figure 8-18. A stationary sleeve assembly is contained within the body. Other parts contained within the body, starting at the inlet port, are a control head, piston and piston subassembly stop rod, a lock spring, and a lock piston and return spring.

Fluid entering the fuse is divided into two flow paths by the control head. The main flow is between the sleeve and body, and a secondary flow is to the piston. Fluid flowing through the main path exerts a force on the lock piston, causing it to move away from the direction of flow, This movement uncovers ports, allowing fluid to flow through the fuse.

The movement of the locking piston also causes a lock spring to release the piston subassembly stop

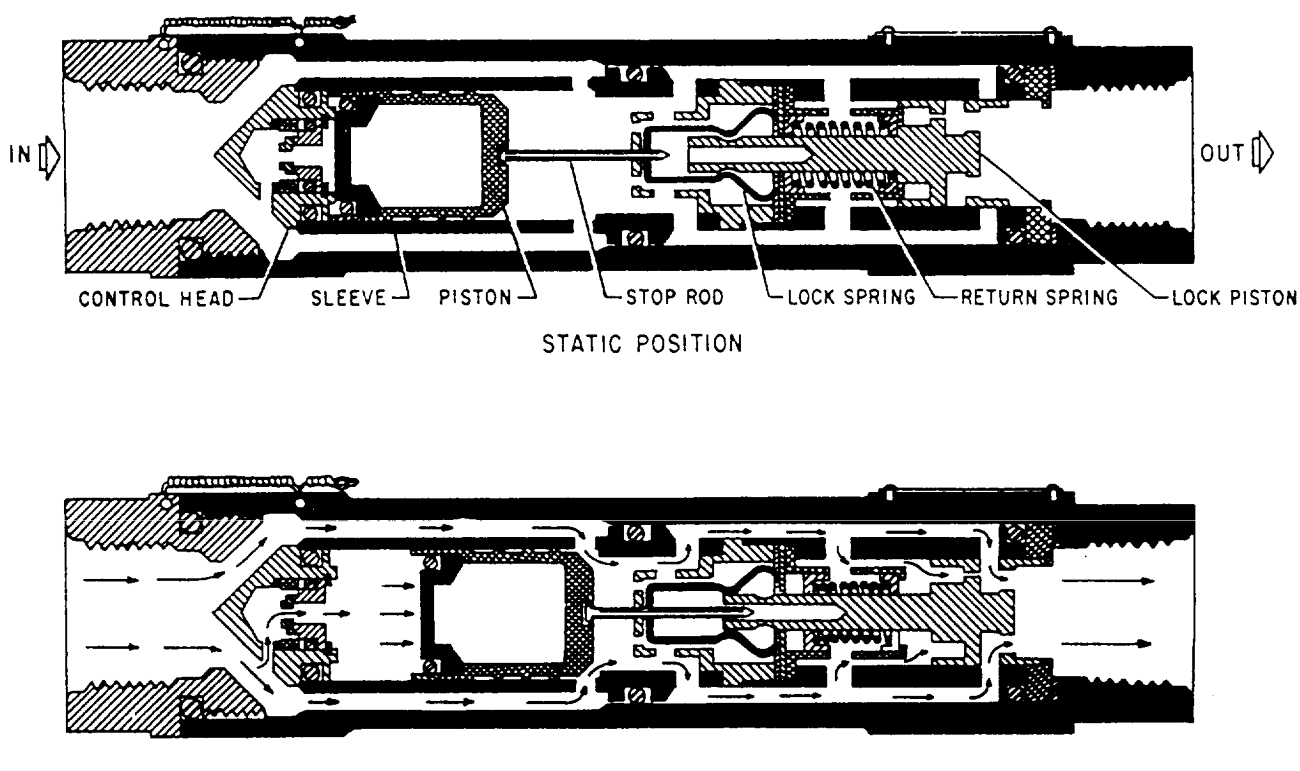


Figure 8-18.—Fuse, operational view.

rod, thus allowing the piston to be displaced by fluid from the secondary flow. If the flow through the fuse exceeds a specified amount, the piston, moving in the direction of flow, will block the ports originally covered by the locking piston, thus blocking the flow of fluid.

Any interruption of the flow of fluid through the fuse removes the operating force from the lock piston. This allows the lock piston spring to return the piston to the original position, which resets the fuse.

RECOMMENDED READING LIST

NOTE: Although the following reference was current when this TRAMAN was published, continued currency cannot be assured. You therefore need to ensure that you are studying the latest revision.

Fluid Power, NAVEDTRA 12964, Naval Education and Training Program Management Support Activity, Pensacola, Florida, July 1990, Chapter 10.